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# A Setback-Drag Simulator

by Donald J. Mary

U.S. Army Electronics Research
and Development Command
**Harry Diamond Laboratories**
Adelphi, MD 20783

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|---|---|
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| Setback | Aerodynamic drag |
| Simulator | Fuze tester |

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The Setback-Drag Simulator is a device for testing the XM754 Viper fuze. The simulator can generate setback forces over a range from 1,500 to 16,000 g and aerodynamic drag forces over a range from 0 to −40 g. The tester and its performance characteristics are described.

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## FOREWORD

The technique described in this report for simulating setback and drag forces was originally proposed by Herbert D. Curchack of Harry Diamond Laboratories (HDL). Experimental verification of the technique was directed by Irvin Pollin of HDL, who also published a theoretical analysis of this method of simulation.

The detailed design of the prototype was developed by Arthur Ball, also of HDL, who supervised the fabrication of the individual parts and assembled the simulator.

CONTENTS

CONTENTS (Cont'd)



APPENDICES



FIGURES

## 1. INTRODUCTION

The Setback-Drag Simulator (herein called the tester) described in this report fulfills the requirements for a procedure to test the XM754 Viper fuze for proper arming. The tester was designed to provide a dynamic environment which produces the necessary time-sequential setback force and drag force to arm this specific fuze.

Briefly, the tester consists of six major assemblies:

(a) A cylindrical test projectile, which houses the fuze(s) to be tested,

(b) An air gun, which propels the test projectile at the proper velocity prior to setback force simulation,

(c) A catch tube, in which the setback and drag forces are simulated and the fuze is armed,

(d) A mitigator and a momentum exchange mass (MEM), which bring the projectile to an abrupt, controlled stop and simulate the setback,

(e) A catch box, into which all the components involved in the simulation are injected after the test, and

(f) A control box, which contains all the controls, switches, and electronic circuits required to operate the tester.

Additional ancillary equipment necessary to complete the tester is described in section 3.8.

## 2. OPERATION OF TESTER

Figure 1 shows the tester. The fuze to be tested is contained in a cylindrical projectile which is placed in the breech end of the gun tube. The projectile seals the breech end of the gun tube by bearing against an O-ring. The projectile is restrained from sliding down the gun tube by a metal dowel (the release pin) projecting through the wall of the gun tube from the outside. These components are shown in figure 2. The muzzle end of the gun is sealed with a thin, plastic (Mylar) diaphragm. A vacuum pump removes the air from the gun tube.

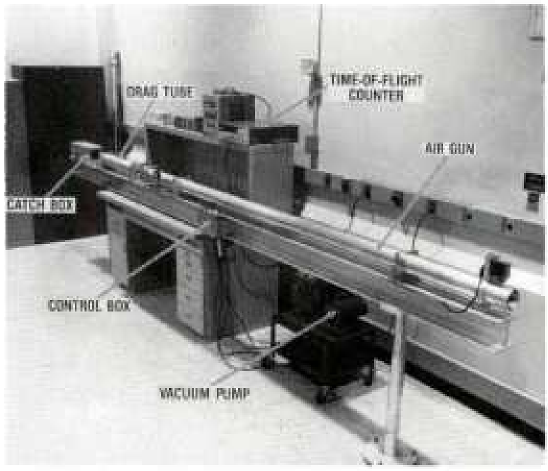


Figure 1. Setback-Drag Simulator—tester.

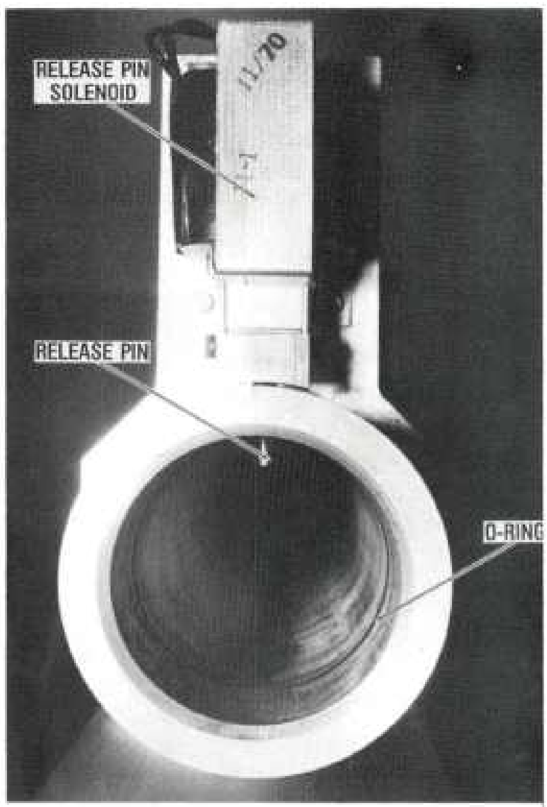


Figure 2. Breech end of air gun.

The gun is fired by withdrawing the release pin, which allows ambient room air pressure to accelerate the projectile along the gun tube. Upon reaching the muzzle end of the gun, the projectile ruptures the plastic diaphragm, then emerges from the air gun, crosses a short gap, and enters the drag tube.

The XM754 fuze requires two distinct forces acting in a specific time sequence to cause arming. The first force, called the setback force, is merely the inertial resistance offered by the components of the round formerly at rest, opposing their acceleration along the gun barrel or launch tube. The second force is the aerodynamic drag which the round experiences during free flight after leaving the muzzle of the weapon. Both forces are required in the proper magnitudes and time sequence to cause the fuze to arm. In the tester, these forces are produced inside the drag tube.

The orientation in the test projectile is such that the base of the fuze points in the direction of travel; this is contrary to the normal position of the fuze in an ordnance round. The acceleration experienced by the test projectile in the air gun is small (less than 150 g) and is directed away from the base of the fuze—a direction opposite that to which the setback force must be applied. As the projectile enters the drag tube, it is brought to a controlled stop. This rapid *deceleration* of the test projectile generates a force on the fuze of the proper magnitude and direction approximately equal to the setback force.

This setback is simulated by allowing the projectile to impact a mitigator between the projectile and a MEM. These items, located in the drag tube, bring the projectile to rest. The MEM absorbs the projectile's momentum, and is ejected from the rear of the drag tube.

The projectile and MEM are circular cylinders. The projectile fits closely within the bore of the drag tube. The body of the MEM is much smaller than the inner diameter of the drag tube, and air would normally flow freely past it. However, a cap (the drag washer) is fitted to the end of the MEM that faces the projectile. The diameter of the drag washer is chosen to obtain the desired air leakage into the cavity formed by the projectile, drag tube, and MEM. (The cross-sectional area of the mitigator is small enough that it does not restrict the flow of air between the MEM and the projectile.)

The drag simulation usually begins 1 or 2 ms after the end of the setback phase. As described above, the projectile comes to a stop at the end of the setback force, and the MEM begins to move along the drag tube. This motion of the MEM increases the volume between the MEM and the projectile. Air cannot leak past the drag washer fast enough to maintian a 1-atm pressure in this cavity. The projectile responds to the pressure difference between its front and rear surfaces and begins to accelerate along the drag tube. This acceleration after setback provides the simulation of aerodynamic drag. Figure 3 shows schematically some of the steps during the simulation.

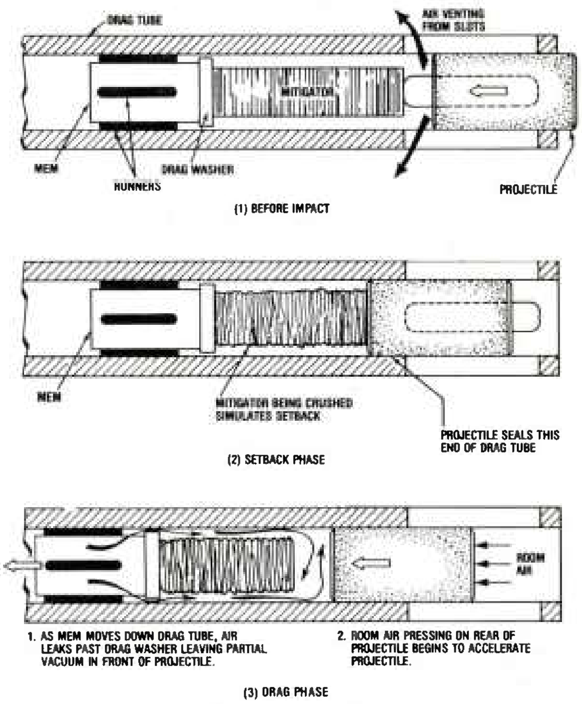


Figure 3. Stages of simulation.

Pollin[1] has provided a complete discussion of the theoretical analysis and some experimental data relating to this method of simulation.

## 3. DESCRIPTION OF TESTER

### *3.1 General*

As shown in figure 1, the main components of the tester are mounted on an aluminum H-beam. The H-beam is 6 in. (15.2 cm) across the flats and 17.5 ft (5.3 m) long. The only components not mounted on this beam are the vacuum pump and an electronic counter. The H-beam in turn may be mounted on a workbench, as shown in figure 1, or on support pedestals anchored to the floor.

### *3.2 Air Gun*

The air gun consists of a gun tube with a release pin and an O-ring in the breech end and an adaptor on the muzzle end. Support brackets fasten the air gun to the H-beam.

#### *3.2.1 Gun Tube*

The gun tube is a smooth-bore aluminum tube with an effective length of 142 in. (335.3 cm). The tube has an internal diameter of about 2.998 in. (7.614 cm) and an outside diameter of 4.0 in. (10.2 cm).

#### *3.2.2 Breech*

The breech end of the gun tube contains an internal O-ring about 3 in. (7.6 cm) forward of the open end. Just in front (toward the muzzle end) of the O-ring is the release pin. This metal dowel protrudes into the bore of the gun tube from the outside. Externally, the release pin is joined to the plunger of a solenoid. The release pin passes through a small bushing in the wall of the gun tube. This bushing contains an O-ring which permits the pin to slide while maintaining a vacuum seal around it. To fire the gun, the solenoid is energized, pulling the release pin up, clear of the projectile. Many of these parts are shown in figure 2.

#### *3.2.3 Adaptor*

The adaptor is a fixture which is clamped (vacuum tight) onto the muzzle end of the gun tube (refer to fig. 4). The adaptor mounts a vacuum line fitting and provides a frame for clamping the plastic diaphragm across the muzzle. When clamped in place, the diaphragm forms an atmospheric seal at this end of the gun tube. Mounted on opposite sides of the adaptor are the two parts of the optical pickup—the light source and the photosensor. The pickup detects the passage of the projectile and supplies a pulse to an electronic counter which then indicates the time of passage. Appendix A describes how this time can be used to compute the muzzle velocity of the projectile.

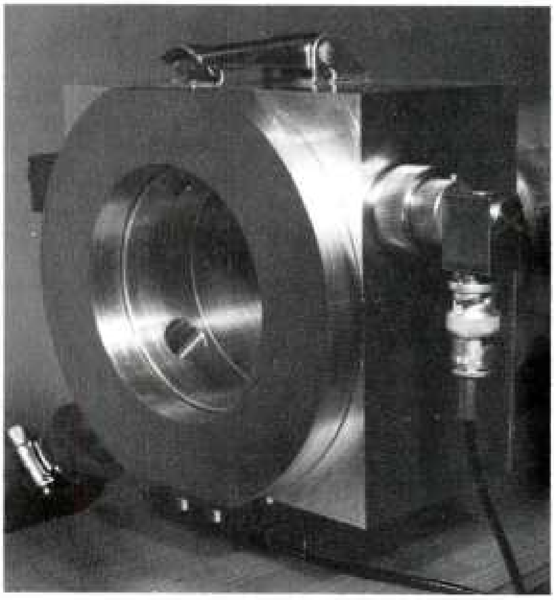

Figure 4. Adaptor.

[1] *Irvin Pollin, Simulation of Sequential Setback and Aerodynamic Drag of Ordnance Projectiles, Harry Diamond Laboratories, HDL-TR-1811 (June 1977).*

### 3.3 Drag Tube

The drag tube is a smooth-bore aluminum tube with an internal diameter of 2.998 in. (7.614 cm) and a length of 30.0 in. (76.2 cm). Four slots cut into the wall of the tube near its entrance serve as vents to allow air to escape as the test projectile enters the drag tube. This venting occurs before impact and facilitates the smooth transition of the projectile into the drag phase of the test after the setback simulation. The slots are equally spaced around the circumference of the drag tube. Each slot is 1.25 in. by 4 in. (3.2 cm by 10.2 cm), with the longer dimension parallel to the longitudinal axis of the tube. The entrance diameter of the tube is slightly larger than the nominal internal diameter. This larger entrance diameter tapers down to the 2.998-in. value over a distance of about 1.25 in. (3.17 cm); the taper eases the projectile into the drag tube.

The support brackets which mount the drag tube to the H-beam have a certain degree of lateral adjustment. This, along with the use of shims to raise or lower the drag tube, provides a means of aligning the drag tube with the gun tube. A special gauge keeps track of the positioning during the alignment process. (See sect. 3.8.8 and app B.)

Figure 5 illustrates some of the features of the drag tube.

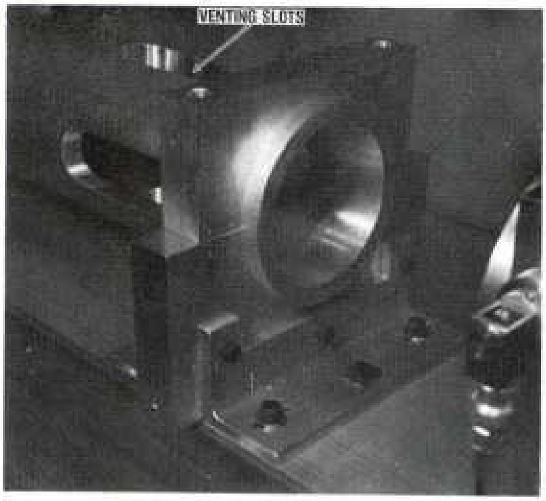


Figure 5. Drag tube.

### 3.4 Catch Box

The catch box is just beyond the rear end of the drag tube, as shown in figure 6. The catch box provides a means of safely catching and retaining those components (the test projectile, the mitigator, and the MEM) that are ejected from the drag tube. The box is fabricated from a 0.5-in. (1.3-cm) thick aluminum sheet and is welded together. The box measures approximately 6.0 × 6.0 × 18.75 in. (15.2 × 15.2 × 47.6 cm) and has a hinged lid and a plywood inner lining. An absorber cut from 450-psi aluminum Hexcel cushions the impact of the MEM against the back of the box.

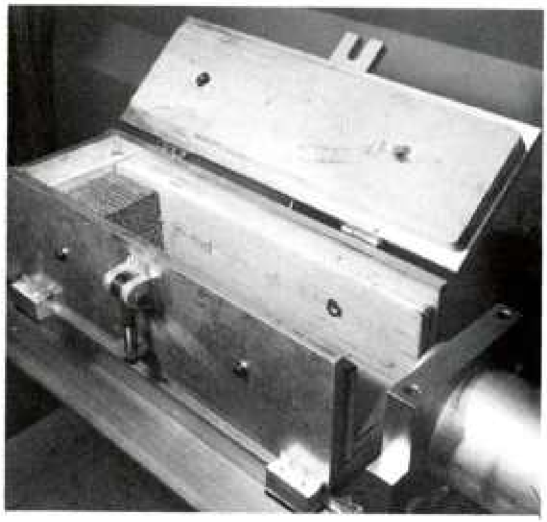

Figure 6. Catch box.

### 3.5 Control Box

The control box requires single-phase, 120-V 60-Hz electrical power rated at 20 A. The control box provides all the switches and electrical power to operate the tester. It contains, besides the 120-Vac circuits, two modular power supplies and an amplifier to operate the optical pickup. The control box is shown in figure 7(a). The wiring diagram is shown in figure 7(b).

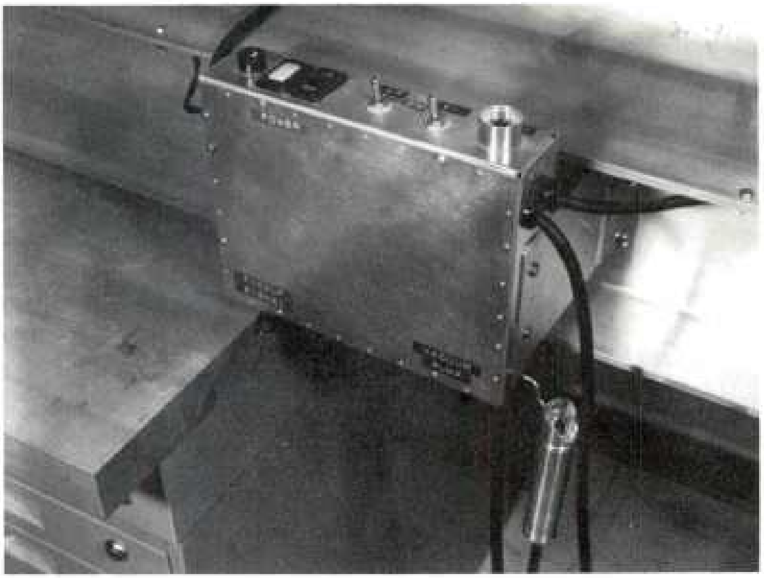

Figure 7(a). Control box—external view.

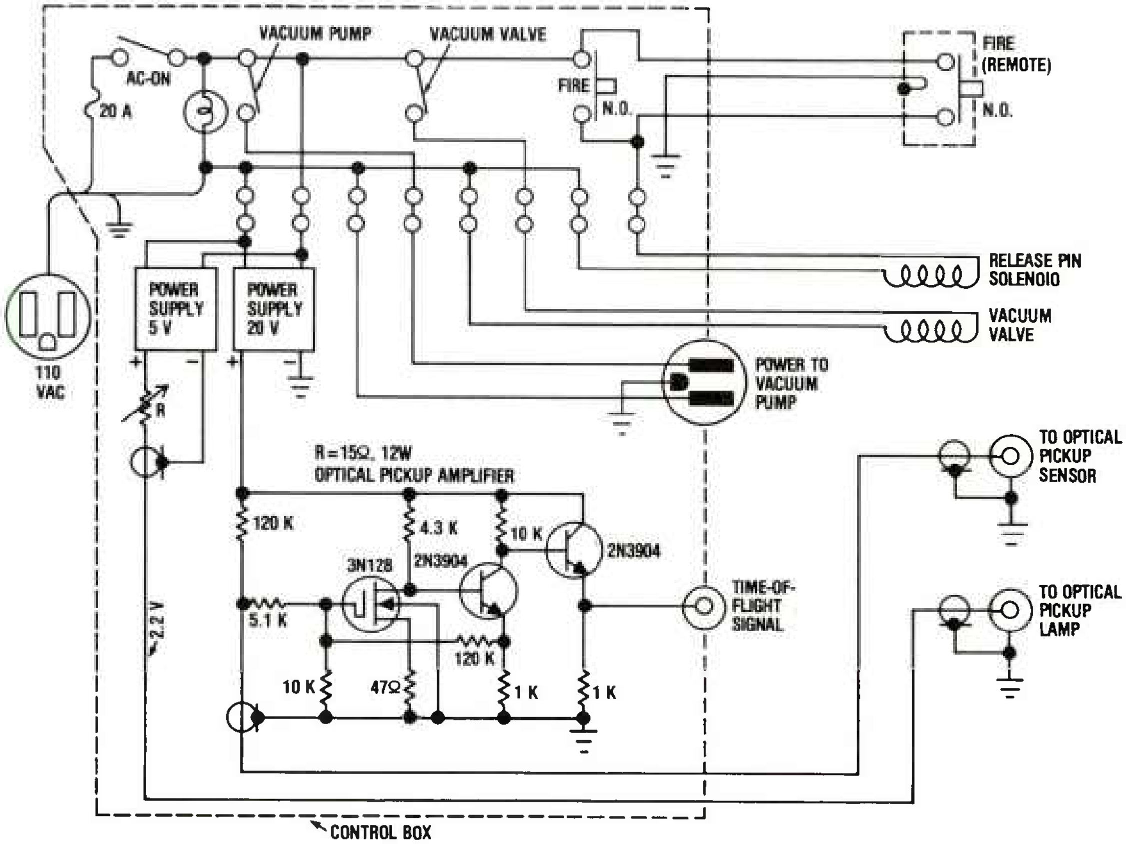


Figure 7(b). Control box—wiring diagram.

### *3.6 Test Projectile*

The test projectile (fig. 8) is fabricated from Bakelite. It is cylindrical, with a diameter of 2.992 in. (7.599 cm) and a length of 3.812 in. (9.682 cm). Three cavities are bored from the rear surface of the projectile. Each cavity accommodates a fuze, so as many as three fuzes may be tested at once. Spacers assure a snug fit of the fuzes in the cavities. Recesses in the spacers allow for the use of safety wiring harnesses or shorting plugs. A metal plate fastens to the rear of the projectile and acts as a cover to retain the fuze samples. This projectile was designed for producing setback forces of about $4.0 \times 10^3$ g. Other projectiles are required to produce higher setback forces. Some of these projectiles are discussed briefly in appendix C.

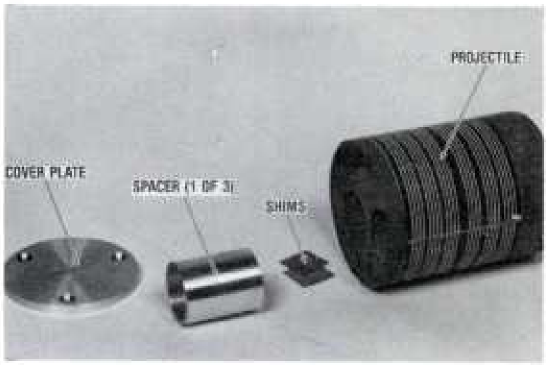


Figure 8. Test projectile (4000 g).

### *3.7 Mitigator-MEM Combination*

The mitigator for the 4000- to 8000-g range consists of 7-ply, 0.75-in. (1.91-cm) thick, plywood blocks cut in the shape of squares 2.0 in. (5.0 cm) on a side. The blocks are cut from marine plywood. Seven blocks are required for one mitigator, and they are held together in a stack with fiberglass-reinforced, self-adhesive tape.

The MEM is a solid brass cylinder, 2.698 in. (6.855 cm) in diameter by 4.06 in. (10.31 cm) long. Four phenolic runners are fastened to its outer surface and machined to an overall diameter of 2.990 in. (7.594 cm). The drag washer has a diameter of 2.850 in. (7.239 cm) and is attached to the front (mitigator end) face of the MEM. The washer regulates the rate at which air leaks into the volume between the MEM and the projectile during the drag simulation. Figure 9 illustrates a mitigator and MEM in the configuration described above.

For setback forces greater than $8.0 \times 10^3$ g, different types of mitigators, MEMs and/or lighter projectiles may have to be used. Some other types are outlined in appendix C.

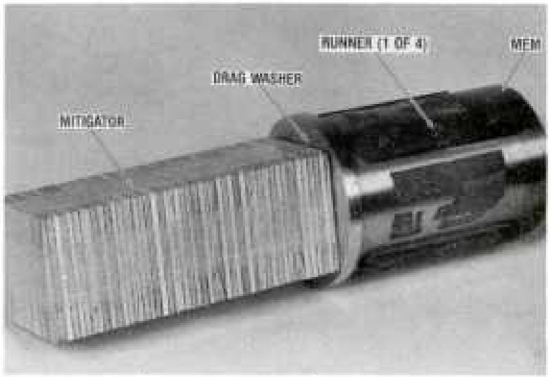


Figure 9. Mitigator-MEM combination (4000 g).

### *3.8 Ancillary Equipment*

Several component parts of the tester not previously mentioned are briefly described below.

*Vacuum Pump.*—A vacuum pump, such as the Welch Duo-Seal Vacuum Pump, Model 1402, or equivalent, is required to evacuate air from the gun tube. The pump motor runs on 120-V, 60-Hz, single-phase power and draws less than 10 A. It can be operated from a switched receptacle on the control box.

*Vacuum Valve.*—An electrically controlled valve is in the vacuum line between the vacuum pump and the air gun. This valve is operated from a switch on the control box and permits the evacuation of air from the gun tube.

*Vacuum Gauge.*—A vacuum gauge connected to the air-gun side of the vacuum valve monitors the degree of vacuum within the gun tube.

*Bleed Valve.*—Mounted near the vacuum gauge, the bleed valve is manually operated and permits the equalization of the air pressure in the gun tube with the atmosphere.

*Electronic Counter.*—An electronic counter connected to the output of the optical pickup amplifier will indicate the time of passage of the projectile past the pickup. Although the counter is not necessary in the operation of the tester, its regular use is a means of monitoring the performance of the tester. The amplified pickup signal appears at the BNC* coaxial receptacle on the bottom of the control box. There is no provision on the control box to supply power to the counter.

*Test Plug.*—The test plug is a dummy projectile which is inserted into the breech end of the gun tube as a seal to check the operation of the vacuum system.

*Alignment Gauge.*—This fixture slips into the muzzle of the gun tube and features an arm which protrudes into the drag tube. A metal finger on the end of the arm contacts the inner surface of the drag tube. A micrometer indicates the displacement of the finger. The misalignment of the drag tube can be deduced from a set of such micrometer readings taken around the inner circumference of the tube. Corrective adjustments of the support brackets will bring the drag tube coaxially in line with the gun tube. The gauge is shown in figure 10. The alignment procedure is discussed in appendix B.

Figure 10. Alignment gauge.

## 4. TESTER DESIGN CRITERIA

Early on, some design criteria were specified by Harry Diamond Laboratories, but were not published formally (Materials Testing Technology: Setback-Drag Tester for S&A Devices, November 1978).

(a) A versatile rather than an automatic tester.

(b) Maximum capability within reasonable space limitations.

(c) Six Viper units to be tested per shot.

(d) 3-in. ID nominal gun diameter, 12-ft long.

(e) Setback range adjustable from 4000 to 8000 g.

(f) Drag adjustable from 0 to 30 g.

(g) Firing of temperature-conditioned fuzes.

*Bayonet N-type Connector

All these design criteria were met, although (c) requires qualifications.

Addressing each of the items above individually will demonstrate to what degree of success these criteria were incorporated into the tester.

*Versatility (a).*—If the tester is made to operate manually, the parameters of the simulation may be considerably varied. Usually, a change in these parameters does not change the operating procedure.

*Capability (b).*—The tester can simulate setback forces over the range from 1,500 g to 16,000 g and drag forces from 0 to −40 g. This can be done only by changing the mitigator-MEM combination, the projectile, and/or the drag washer. No changes in the tester are necessary.

*Test Quantity (c).*—Originally, the projectile described in section 3.6 was designed to accommodate six fuzes at one time. It was reconfigured later to accept only three fuzes, but these fuzes could be tested with or without wiring harnesses and/or shorting connectors. To test six fuzes at one time would require a projectile similar to that already described, but with a redesigned interior. Such a projectile has not been fabricated. At setback forces higher than $4.0 \times 10^3$ g, only one fuze can be tested at a time because of the weight restrictions imposed on the projectile.

*Dimensions (d).*—The originally specified dimensions have been adopted as set forth in section 3.2.1.

*Setback Range (e).*—As the setback simulation approaches the 8000-g level, and larger, the weights of the projectile and MEM must be changed. At still higher setback levels, the type of mitigator material is changed. Some of these different combinations are described in appendix C.

*Drag Level (f).*—The drag force is easily varied by changing the diameter of the drag washer on the MEM. This controls the rate at which air leaks into the space between the MEM and the projectile. The air leak rate, in turn, controls the acceleration of the projectile during drag simulation.

*Temperature Conditioning (g).*—Generally, testing temperature-conditioned fuzes presents no problem, so long as extensive pretest handling of the fuzes is avoided. The fuzes can be loaded into the projectile in less than one minute and the test can be completed less than a minute after that. Wiring harnesses or shorting plugs connected to the fuzes complicate the insertion of the fuzes into the projectile, but not excessively so. Any pretest handling, of course, will cause the temperature of the fuzes to change by some indeterminate amount.

## 5. EVALUATION OF TESTER PERFORMANCE

### *5.1 General*

By December 1980, a total of 205 tests had been performed with one of the setback-drag simulators, and 70 tests performed with a second tester. Of the tests performed on the first tester, a few of the earlier ones had been to verify the tester's performance. The majority, however, had been performed on Viper fuzes and components supplied by government and contractor sources. It was demonstrated that a series of tests conducted with the same test parameters produced repeatable setback and drag force levels.

### *5.2 Evaluation Technique*

Evaluation of the tester (which is tantamount to a calibration of the tester) involves photographing the test projectile during setback and into the beginning of the drag simulation. A pattern of alternate black and white stripes printed on paper fastened around the circumference of the projectile becomes the object for the streak camera. (See fig. 8.) The streak camera produces a displacement-time curve of the stripe pattern. The resulting camera negative is scanned by a film analysis system (a computer-controlled microdensitometer), and the photographic image is digitized and stored on magnetic tape. Later this information is processed by a computer, and a printout of the acceleration-time curve is obtained.

The streak camera is positioned to view the projectile (stripe pattern) through one of the vent slots in the drag tube. The camera records projectile travel before, during, and after impact. This yields data relating to impact velocity, setback force, and drag force. The total time interval recorded during the exposure is limited by the on-time of the illuminating flash and is usually about 10 ms.

The results of a test are shown in figures 11(a), (b), (c), (d), and (e). Figure 11(a) is the front sheet of the file copy of the test report and contains at least all the data that appears on the customer's copy. The front sheet is generated after the test but before the film is analyzed. The results shown near the middle of the page, where the average and peak accelerations, stopping distance, and impact time values are presented, are based on computations using a theoretical model. The impact velocity is derived from the optical pickup signal (photocell time) and the projectile length and is a measured quantity. The lower third of the page gives certain information regarding the camera and film parameters. This information is input data for the film analysis system.

Figure 11(b) is the tabular data generated by the computer from the digitized film record. The column headings are self-explanatory. Normally, zeros in the TIME and TRAVEL columns represent the instant of contact of the projectile with the mitigator and mark the beginning of the setback simulation. However, the zero point is computed from the geometric relation between the front surface of the mitigator and the center of the camera field of view. A small error in their positions will be reflected in the tabular data and on the graph. In this test, then, impact occurs at the onset of setback, that is, between −2.8 and −0.9 mm (−0.110 and −0.035 in.) in the TRAVEL column. The projectile speed at this point is 77.3 m/s (255 ft/s), which is about 1 m/s (3.3 ft/s) less than the speed derived from the optical pickup data shown on the front page. The tabular data are plotted in figure 11(c).

The graph of the setback force versus time indicates the error in the position of zero time. (This misplacement of the zero on the time axis is merely a cosmetic defect in the data and has no real effect on the final results.) The graph indicates that the total setback pulse lasted about 1.3 ms. The smooth curve without indicated data points is the velocity of the projectile.

Figure 11(d) is the tabular data relating to the drag phase of the test. Zero in the TIME column corresponds to the zero time in the setback data; that is, the moment of impact. (This correspondence of zero time was not a feature in the output data from tests early in the program. Such lack of correspondence is discussed in sections 5.3.1.1 and 5.3.2.2.) The data indicate that the drag began at about 2.56 ms and lasted beyond the end of the record. After an initial pulse of about −60 g, the drag force varied from −20 to −10 g. This can best be seen from the graph in figure 11(e). The entire portion of the drag simulation photographed by the camera results from a movement of the projectile of only 4 mm (0.16 in.).

A graph plotted from the drag tabular data is shown in figure 11(e). Again, the smooth curve is the projectile velocity, while the graph with data points is the drag force.

```
        S E T B A C K - D R A G   T E S T E R   R E P O R T
Shot Number 154              Time 1005 Hours                  23-JUN-80
                         Project -- 852886
                       Requestor -- Mr. SUGARMAN
                       Component -- VIPER
                  Unit Number(s) -- T-9
                     Temperature -- 70 F, 21 C
PROJECTILE #6 (FLAT Nose)
                          Weight     0.948 lb            0.430 kgm
                          Length     3.24  in.           8.23  cm
GUN  (Evacuated Barrel)
                 Inside Diameter     2.99  in.           7.61  cm
                  Overall Length    11.83  ft            3.61  m
                 Firing Pressure    14.70  psia          1.00  atm abs
                  Photocell Time  1047.0   microsec
     Non-Dimensional Length          0.0377
                     Performance    91.3   %
MITIGATOR (Mounted on MEM)
     2X2 in. PLYWOOD SQUARE
                          Weight     7.16  oz          203.    gm
                  Initial Length     5.25  in.          13.34  cm
                  Crushed Length     4.38  in.          11.13  cm
MOMENTUM EXCHANGE MASS (MEM)
weight (not including Mitig          4.67  lb            2.12  kgm
DRAG TUBE
            MEM Washer Diameter      2.850 in.           7.24  cm
    Initial Mitigator Depth          4.50  in.          11.43  cm
  Bird traversed drag tube into catcher.
RESULTS
    Max Launch Acceleration   109.2    g
            Impact Velocity   258.     ft/s             78.6   m/s
    A Constant Setback Assumption Yields:
          Stopping Distance     1.6    in.               4.1   cm
       Average Acceleration     7.7    kilo-g
               Impact Time      1.04   ms
    Previous tests using this type of mitigator imply:
          Peak Acceleration     8.5    kilo-g
COMMENTS:
Camera Operator, Mr. NELSON.    (Speed 48.2 rps)
Test Performed by Mr. NELSON, Branch 48500, ext 42804.
                                     DENSITY OF STRIPES ___185_____

                                DENSITY BETWEEN STRIPES ____51_____

                                                    SUM __236_____

                                      SUM DIVIDED BY 2 ___118_____

                                              SUBTRACT      2 0

                                       T H R E S H O L D ____98_____
X STEP = 1200 (REPRESENTS 25 MICROSECOND TIME INTERVALS)
NUMBER OF SCANS = 859 (70 MM FILM)    22 SCANS PER INCH

TAN < = 1.45683            TRAVEL PER INTVL = 1.7482 MM
ON DRAG PORTION - X STEP = 9600 (REPRESENTS 200 MICROSECOND TIME INTERVALS)
NUMBER OF SCANS = 118 (70 MM FILM)    3 SCANS PER INCH

TAN < = 1.45683            TRAVEL PER INTVL = 13.9856 MM
C A U T I O N: CONSIDER CUTTING X STEP IN HALF!

IDENT....0154 SAD XXXX (THRESHOLD)
```

Figure 11(a). Typical test report—front sheet.

SHOT NUMBER 0154     23-JUN-80     PAGE 1 OF 1

| TIME MSEC | TRAVEL MM | SPEED M/SEC | SETBACK KILO G |
|---|---|---|---|
| -0.24 | -18.1 | | |
| -0.21 | -16.2 | 76.9 | |
| -0.19 | -14.3 | 76.7 | 0.24 |
| -0.16 | -12.4 | 76.7 | -0.67 |
| -0.14 | -10.5 | 77.0 | -1.47 |
| -0.11 | -8.6 | 77.5 | -1.12 |
| -0.09 | -6.7 | 77.6 | 0.03 |
| -0.06 | -4.8 | 77.4 | 0.58 |
| -0.04 | -2.8 | 77.3 | 0.27 |
| -0.01 | -0.9 | 77.3 | 2.15 |
| 0.01 | 1.0 | 76.2 | 7.97 |
| 0.04 | 2.8 | 73.4 | 9.71 |
| 0.06 | 4.6 | 71.5 | 6.58 |
| 0.09 | 6.4 | 70.2 | 6.40 |
| 0.11 | 8.1 | 68.4 | 7.97 |
| 0.14 | 9.7 | 66.3 | 7.88 |
| 0.16 | 11.3 | 64.5 | 6.76 |
| 0.19 | 12.9 | 63.0 | 6.82 |
| 0.21 | 14.4 | 61.2 | 7.43 |
| 0.24 | 15.9 | 59.4 | 6.70 |
| 0.26 | 17.4 | 57.9 | 6.22 |
| 0.29 | 18.8 | 56.3 | 6.33 |
| 0.31 | 20.2 | 54.8 | 5.55 |
| 0.34 | 21.5 | 53.6 | 4.86 |
| 0.36 | 22.8 | 52.4 | 5.32 |
| 0.39 | 24.1 | 51.0 | 5.96 |
| 0.41 | 25.3 | 49.5 | 6.39 |
| 0.44 | 26.5 | 47.9 | 6.59 |
| 0.46 | 27.7 | 46.3 | 6.64 |
| 0.49 | 28.8 | 44.7 | 6.77 |
| 0.51 | 29.9 | 43.0 | 6.40 |
| 0.54 | 30.9 | 41.5 | 5.39 |
| 0.56 | 31.9 | 40.3 | 4.87 |
| 0.59 | 32.9 | 39.2 | 5.35 |
| 0.61 | 33.9 | 37.7 | 5.84 |
| 0.64 | 34.8 | 36.3 | 5.92 |
| 0.66 | 35.7 | 34.8 | 6.35 |
| 0.68 | 36.5 | 33.2 | 6.31 |
| 0.71 | 37.3 | 31.8 | 5.56 |
| 0.73 | 38.1 | 30.5 | 5.70 |
| 0.76 | 38.8 | 29.0 | 6.38 |
| 0.78 | 39.5 | 27.4 | 6.49 |
| 0.81 | 40.2 | 25.8 | 6.66 |
| 0.83 | 40.8 | 24.1 | 7.14 |
| 0.86 | 41.3 | 22.3 | 7.28 |
| 0.88 | 41.9 | 20.6 | 7.36 |
| 0.91 | 42.4 | 18.7 | 7.78 |
| 0.93 | 42.8 | 16.7 | 8.23 |
| 0.96 | 43.2 | 14.7 | 8.01 |
| 0.98 | 43.5 | 12.8 | 7.02 |
| 1.01 | 43.8 | 11.3 | 6.40 |
| 1.03 | 44.1 | 9.7 | 6.08 |
| 1.06 | 44.3 | 8.3 | 5.42 |
| 1.08 | 44.5 | 7.1 | 4.78 |
| 1.11 | 44.6 | 6.0 | 4.08 |
| 1.13 | 44.8 | 5.1 | 3.83 |
| 1.16 | 44.9 | 4.1 | 3.68 |
| 1.18 | 45.0 | 3.3 | 2.88 |
| 1.21 | 45.1 | 2.7 | 2.23 |
| 1.23 | 45.1 | 2.2 | 1.78 |
| 1.26 | 45.2 | 1.8 | 1.34 |
| 1.28 | 45.2 | 1.5 | 1.04 |
| 1.31 | 45.2 | 1.3 | 0.76 |
| 1.33 | 45.3 | 1.2 | 0.57 |
| 1.36 | 45.3 | 1.0 | 0.73 |
| 1.38 | 45.3 | 0.8 | 0.97 |
| 1.41 | 45.3 | 0.6 | 0.64 |
| 1.43 | 45.4 | 0.5 | 0.16 |
| 1.46 | 45.4 | 0.5 | 0.07 |
| 1.48 | 45.4 | 0.5 | 0.20 |
| 1.51 | 45.4 | 0.4 | 0.36 |
| 1.53 | 45.4 | 0.3 | 0.30 |
| 1.56 | 45.4 | 0.2 | 0.00 |
| 1.58 | 45.4 | 0.3 | -0.09 |
| 1.61 | 45.4 | 0.3 | 0.05 |
| 1.63 | 45.4 | 0.3 | -0.07 |
| 1.66 | 45.4 | 0.3 | 0.15 |
| 1.68 | 45.4 | 0.2 | 0.40 |
| 1.71 | 45.4 | 0.1 | 0.10 |
| 1.73 | 45.4 | 0.1 | 0.12 |
| 1.76 | 45.4 | 0.1 | 0.23 |
| 1.78 | 45.4 | 0.0 | 0.12 |
| 1.81 | 45.4 | 0.0 | 0.19 |
| 1.83 | 45.4 | -0.1 | 0.15 |
| 1.86 | 45.4 | -0.1 | -0.14 |
| 1.88 | 45.4 | 0.0 | -0.25 |
| 1.90 | 45.4 | 0.1 | 0.00 |
| 1.93 | 45.4 | 0.0 | 0.19 |
| 1.95 | 45.4 | 0.0 | -0.01 |
| 1.98 | 45.4 | 0.0 | |
| 2.00 | 45.4 | | |

Figure 11(b). Typical test report—setback tabular data.

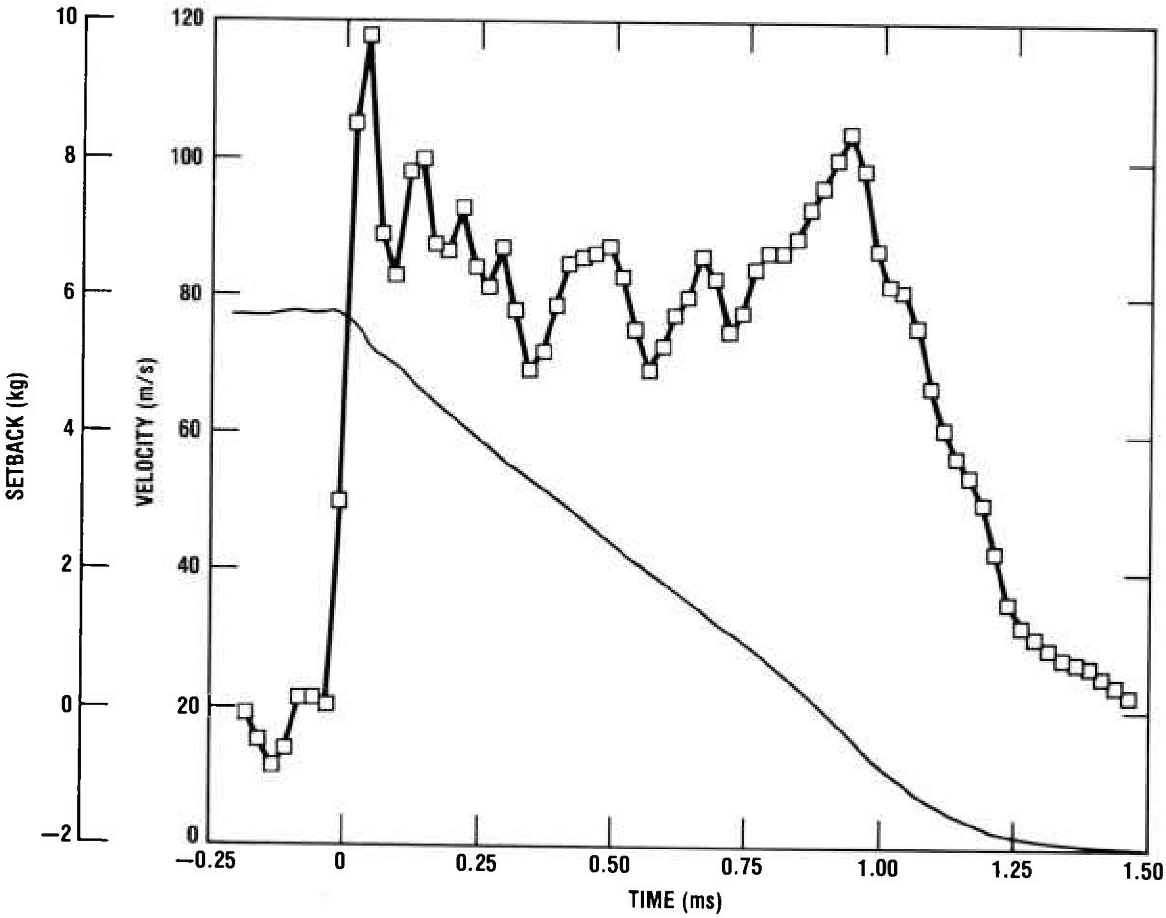


Figure 11(c). Typical test report—setback-time graph.

SHOT NUMBER D154 23-JUN-80 PAGE 1 OF 1

| TIME MSEC | TRAVEL MM | SPEED CM/SEC | SETBACK G |
|---|---|---|---|
| -0.10 | -7.5 | | |
| 0.10 | 7.3 | 6868.6 | |
| 0.30 | 19.6 | 5608.6 | 6275.92 |
| 0.50 | 29.5 | 4415.0 | 6073.00 |
| 0.70 | 37.0 | 3234.3 | 6336.83 |
| 0.90 | 42.2 | 1937.6 | 6270.56 |
| 1.09 | 44.6 | 782.8 | 4435.39 |
| 1.29 | 45.3 | 203.6 | 1872.03 |
| 1.49 | 45.4 | 51.0 | 483.27 |
| 1.69 | 45.5 | 14.7 | 127.38 |
| 1.89 | 45.5 | 1.2 | 41.96 |
| 2.09 | 45.5 | -1.7 | 24.32 |
| 2.29 | 45.5 | -8.4 | 31.19 |
| 2.49 | 45.5 | -13.9 | 4.31 |
| 2.69 | 45.4 | -10.0 | -46.72 |
| 2.89 | 45.4 | 4.3 | -72.97 |
| 3.09 | 45.5 | 18.5 | -48.93 |
| 3.29 | 45.5 | 23.5 | -18.21 |
| 3.48 | 45.6 | 25.6 | -15.45 |
| 3.68 | 45.6 | 29.5 | -22.90 |
| 3.88 | 45.7 | 34.6 | -20.37 |
| 4.08 | 45.7 | 37.5 | -15.61 |
| 4.28 | 45.8 | 40.7 | -19.06 |
| 4.48 | 45.9 | 44.9 | -23.01 |
| 4.68 | 46.0 | 49.7 | -25.98 |
| 4.88 | 46.1 | 55.1 | -26.75 |
| 5.08 | 46.2 | 60.1 | -15.20 |
| 5.28 | 46.3 | 61.0 | -6.52 |
| 5.48 | 46.5 | 62.7 | -16.90 |
| 5.68 | 46.6 | 67.6 | -21.54 |
| 5.87 | 46.7 | 71.1 | -13.27 |
| 6.07 | 46.9 | 72.8 | -6.55 |
| 6.27 | 47.0 | 73.7 | -8.87 |
| 6.47 | 47.2 | 76.3 | -15.37 |
| 6.67 | 47.3 | 79.7 | -16.98 |
| 6.87 | 47.5 | 82.9 | -16.43 |
| 7.07 | 47.6 | 86.1 | -13.66 |
| 7.27 | 47.8 | 88.3 | -9.06 |
| 7.47 | 48.0 | 89.6 | -3.45 |
| 7.67 | 48.2 | 89.6 | -2.60 |
| 7.87 | 48.3 | 90.6 | -5.84 |
| 8.07 | 48.5 | 91.9 | -5.65 |
| 8.26 | 48.7 | 92.9 | -15.78 |
| 8.46 | 48.9 | 98.1 | -25.47 |
| 8.66 | 49.1 | 102.8 | |
| 8.86 | 49.3 | | |

Figure 11(d). Typical test report—drag tabular data.

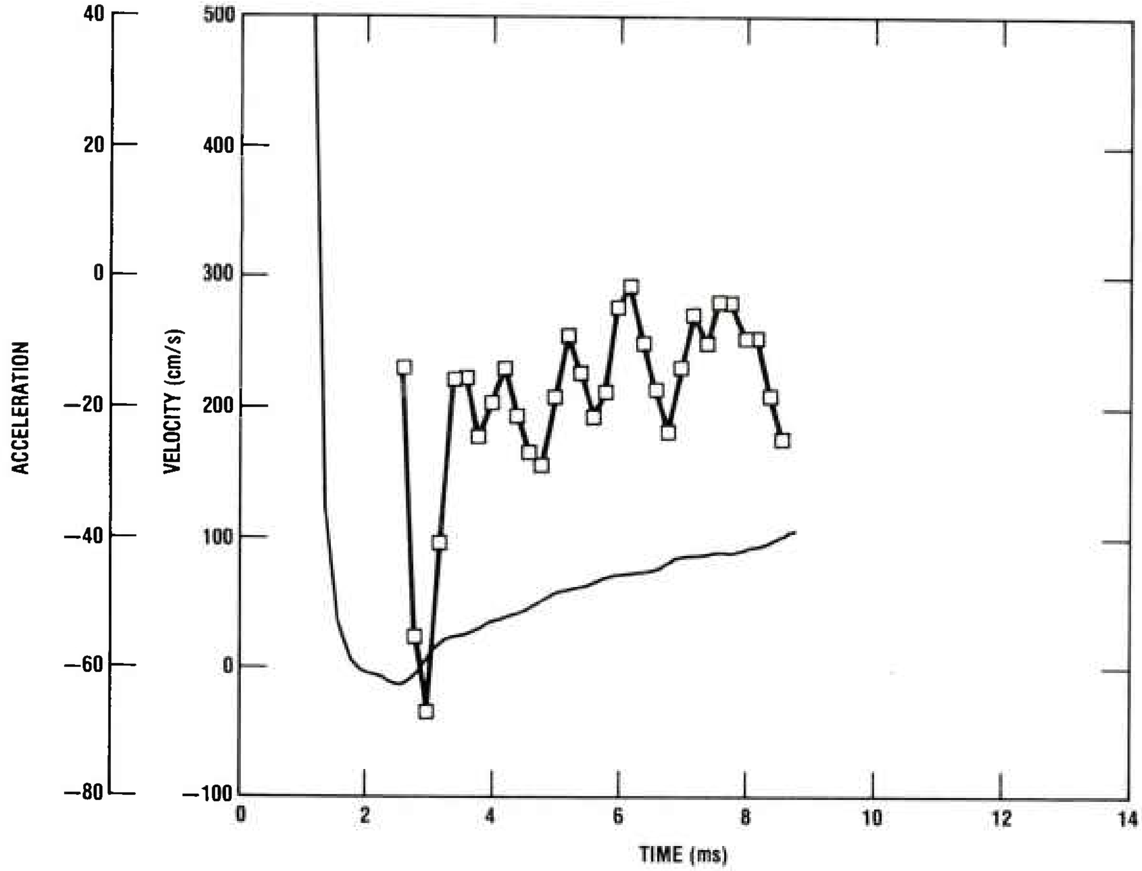


Figure 11(e.) Typical test report—drag-time graph.

*5.3 Repeatability*

*5.3.1 Setback Simulation*

*5.3.1.1 $4.0 \times 10^3$-g Level*

A series of 10 tests was analyzed. These tests were conducted using the same test parameters. (See app D.) Figure 12 is the graph plotted of the average values, taken at 0.05-ms intervals, of all 10 setback curves. Because of slight variations in the positions of the curves relative to zero time, all curves were shifted along the time axis until the steep rises of the curves matched. Zero on the time axis was then arbitrarily positioned at the onset of setback. No adjustments in the curves were made along the vertical axis. As plotted, the average values ± one standard deviation are indicated every 0.05 ms. From these data it may be said with 95-percent confidence that at least 87.5 percent of all similar tests will produce peak setback forces of $4.0 \times 10^3$ g or higher. At least 95 percent of all the tests will peak at $3.7 \times 10^3$ g or higher, also at 95-percent confidence.[2]

[2]*For methods of computation and confidence tables, see R. M. McClung, First Aid for Pet Projects Injured in the Laboratory or on the Range, or What to do Until the Statistician Comes, Naval Weapons Center, China Lake, CA, NOTS Tech. Memo. No. 1113 (January 1952).*

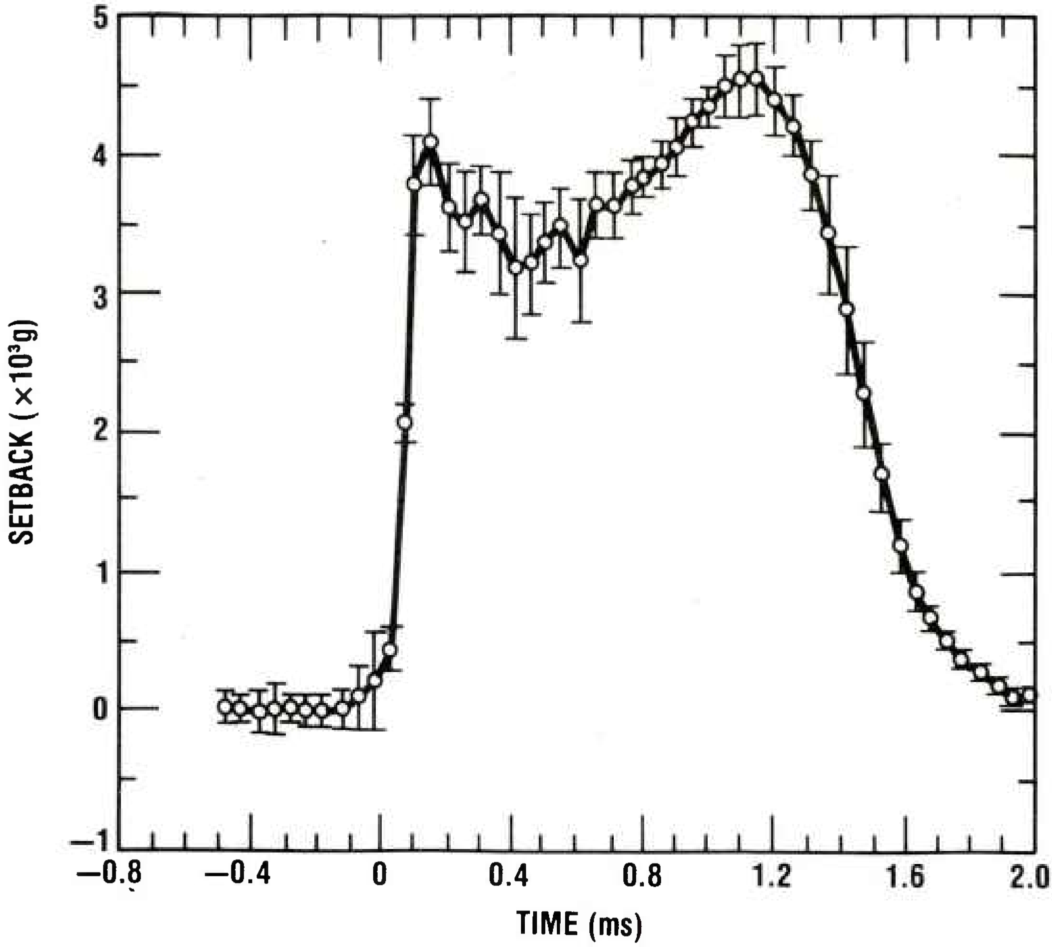


Figure 12. Setback simulation ($4 \times 10^3$ g).

*5.3.1.2 $8.0 \times 10^3$-g Level*

A series of 13 tests was analyzed that were designed to produce $8.0 \times 10^3$-g peak setback. (See app D for test parameters.) Figure 13 is a graph plotted from the average values, taken at 0.05-ms intervals, of all 13 setback curves. The peak value of the setback force, on the average, only reaches $7.9 \times 10^3$ g. As plotted, the average values are shown ± one standard deviation. From these data, one can say with 95-percent confidence that at least 87.5 percent of all similar tests will produce peak values equal to or greater than 6.61 $\times 10^3$ g, and at least 95 percent of all such tests will produce peak values equal to or greater than $6.06 \times 10^3$ g.

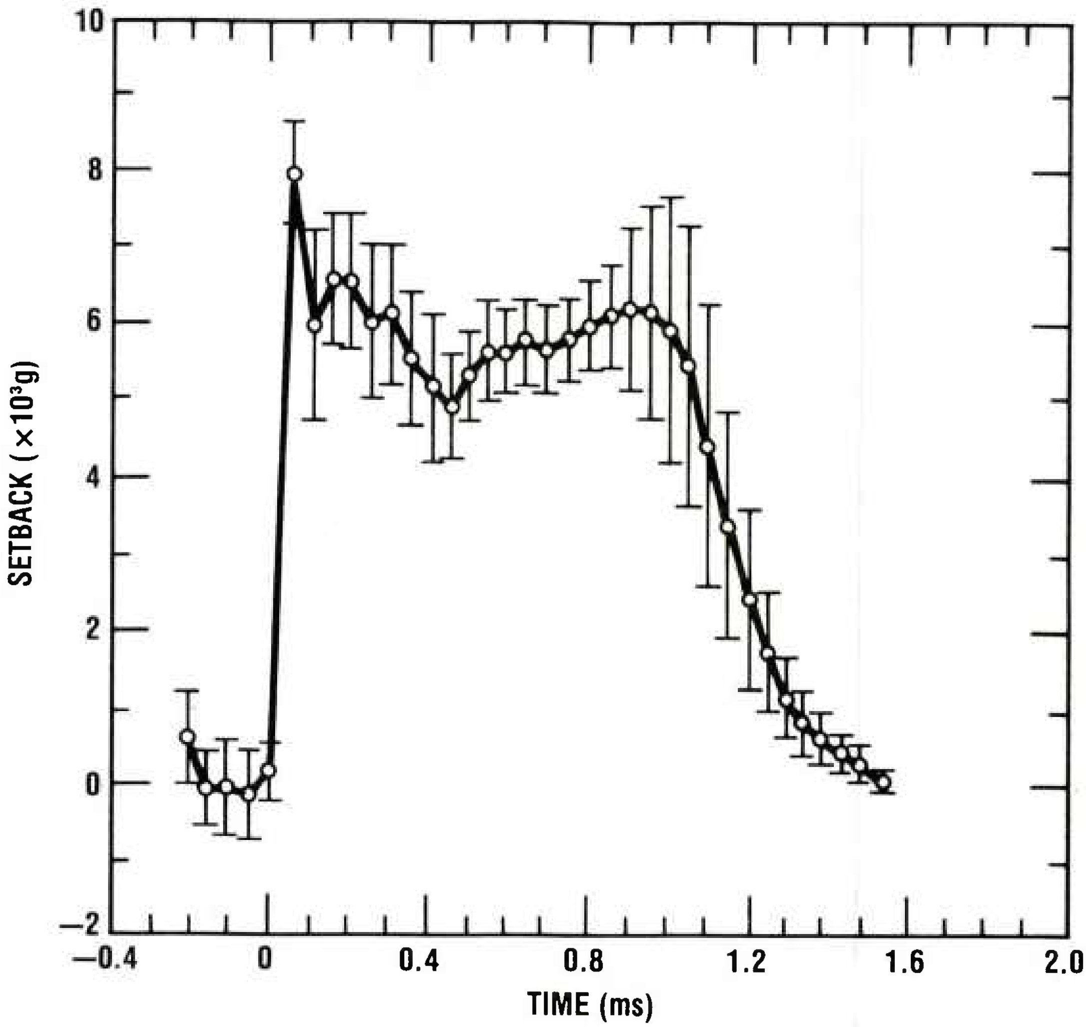


Figure 13. Setback simulation ($8 \times 10^3$ g).

*5.3.1.3 $16.0 \times 10^3$-g Level*

By using aluminum tubecore for the mitigator instead of plywood blocks and by adjusting the weight of the projectile and MEM, setback forces of $16 \times 10^3$ g can be obtained. (Again, refer to app D for parameters.) The results of the tests with the higher setback force are indicated in figure 14. This graph is a plot of the average values ± one standard deviation of all 10 tests computed at 0.05-ms intervals. From these data it may be said with 95-percent confidence that at least 87.5 percent of all similar tests will produce peak setback forces of $15.9 \times 10^3$ g or higher. At least 95 percent of all tests will peak at $14.6 \times 10^3$ g or higher, also at 95-percent confidence.

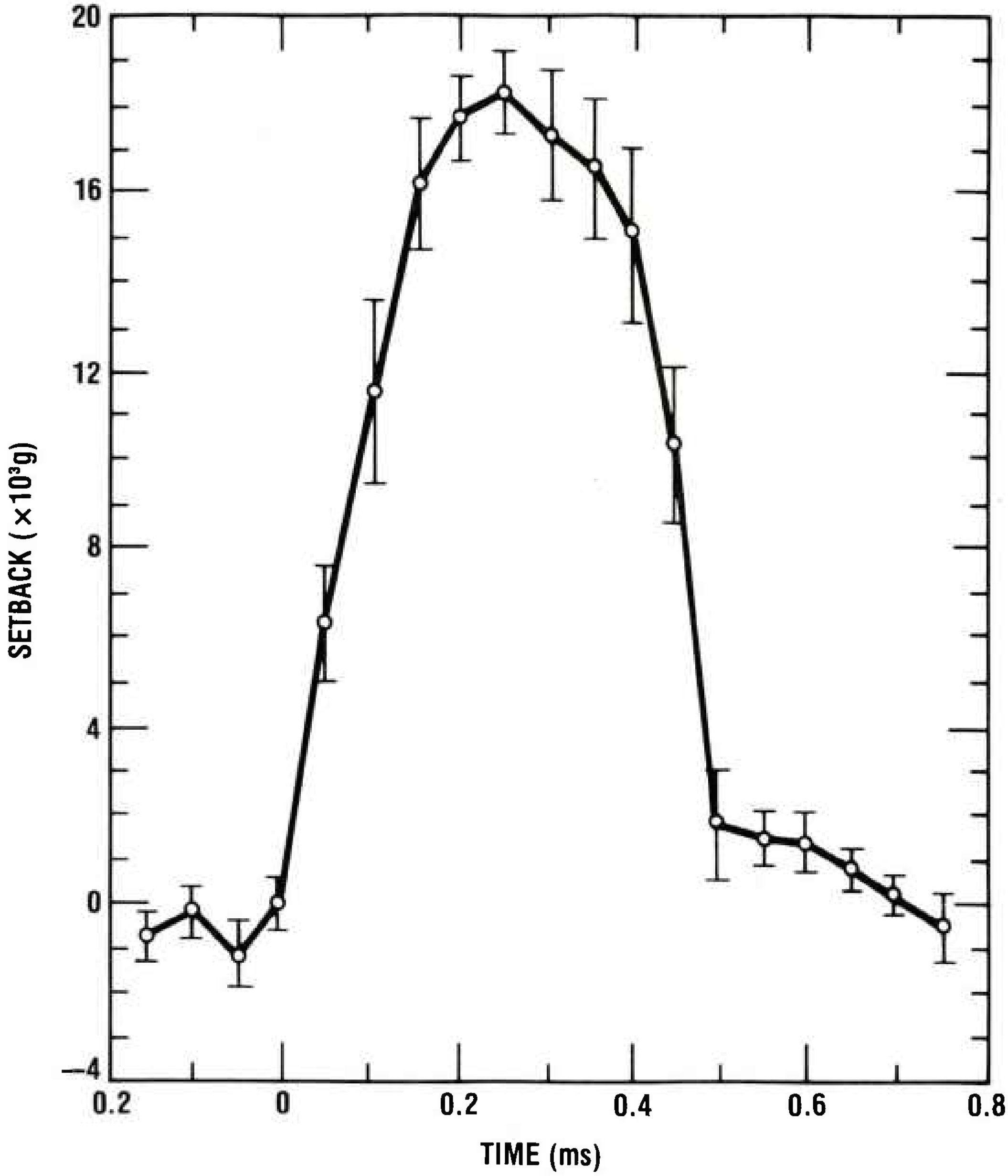


Figure 14. Setback simulation (16 × $10^3$ g).

### 5.3.2 *Drag Simulation*

#### 5.3.2.1 *General*

The curves of drag force amplitude as a function of time are not as well defined and uniform as the setback pulses. Figure 11(e) is typical. Drag simulation occurs whenever the action takes place in the region of negative values on the acceleration scale. There is usually an initial pulse of large amplitude. The pulse may either point up or down. The drag force per se begins after this initial fluctuation and has superimposed upon it oscillations of about 20-g peak-to-peak amplitude at about a 1000-Hz frequency. The magnitude of the drag force has tacitly been assumed to be the smooth curve one might trace by eye through the median of the oscillations. Thus, in figure 11(e) the average drag force seems to be about −20 g at 3.5 ms and decreases to about −10 at 8.0 ms.

There is, unfortunately, no physical evidence available to the operator after a test that drag forces of the proper magnitude have been generated. Whereas the average value of the setback force can be computed from the amount of mitigator crush (and other factors), there is no such indirect measurement which leads to a determination of drag force. The fact that the projectile ends up in the catch box says nothing about how it got there. So far, the analysis of the streak camera film has been the only source of drag force data. (Obviously, successful or unsuccessful arming of the fuze under test is not bona fide evidence of the presence or absence of drag force.)

Analysis of streak camera data, however, does indicate a persistence in the occurrence of drag force from test to test as well as a reasonable repeatability of drag force amplitude. For a given set of test parameters, the drag force increases with an increase in the diameter of the drag washer. (See sections 2 and 3.7.) For a given size drag washer, the drag force increases as the weight of the projectile decreases.

#### 5.3.2.2 *$4.0 \times 10^3$-g Setback Tests*

The tests described in section 5.3.1.1 were analyzed to determine the extent of the drag simulation. Two problems became apparent immediately. First, only 7 of the original 10 tests had drag data suitable for analysis. Second, there was no commonality in the position of zero time from test to test. The reduced number of tests probably degrades the statistical analysis. A lack of commonality on the time axis leads to uncertainty in the alignment of the graphs for computing mean values. For this analysis, the curves were slipped along the time axis until the initial large negative acceleration pulse was centered on zero time. The result of this manipulation is shown in figure 15. The parameters for these tests are shown in appendix D.

The average curve of the seven tests indicated negligible drag force between 3 and 5 ms. By the end of the record the drag force has increased to about −8 g. The indicated data points show the average values ± one standard deviation. The deviation does not decrease as time increases, indicating little or no improvement in the distribution of data from the individual tests with time. One is forced to conclude that drag simulation under these test conditions is marginal. More consistent operation might be obtained by decreasing the weight of the test projectile or increasing the diameter of the drag washer, or both.

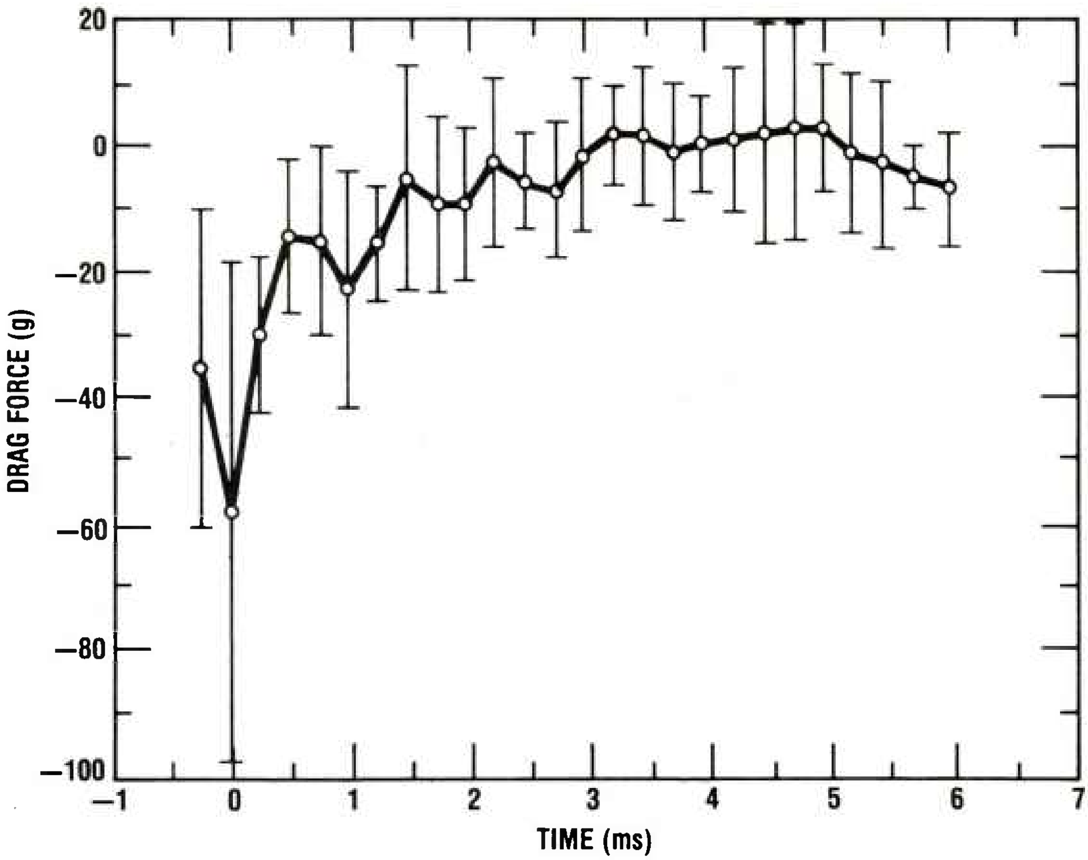


Figure 15. Drag simulation ($4 \times 10^3$-g setback level).

*5.3.2.3 $8.0 \times 10^3$-g Setback Tests*

Drag simulation during these tests was well defined and repeatable. The drag data come from the tests analyzed for the $8.0 \times 10^3$-g setback simulation discussed in section 5.3.1.2 and appendix D. Figure 16 shows the average values ± one standard deviation of 13 tests. For these tests there was correspondence of zero on the time axis, so no adjustment of the curves was necessary. In fact, zero time here corresponds to zero time on the average setback curve shown in figure 13. The only difference in this series of tests and those conducted at the $4.0 \times 10^3$-g setback level was the weight of the projectile. For these tests the projectile weight was 425 grams (0.936 lb), while for the $4.0 \times 10^3$-g tests the weight was 718 grams (1.58 lb). This decrease in weight seems to account for the improvement of drag simulation. The drag force is well defined, and the value of the standard deviation becomes progressively smaller as time increases. At 8.6 ms, for example, the average value for the 13 tests is −16 ± 5.5 g. This leads to the conclusion that, at this point, 90 percent of the tests will produce drag forces between −1.8 and −30.2 g with 95-percent confidence. Also with 95-percent confidence one can say that 87.5 percent of all tests will produce a drag force of at least −5.5 g at the 8.6-ms time mark. The assumption is that, since the deviations are getting progressively smaller with time, the performance beyond 8.5 ms should continue to be acceptable.

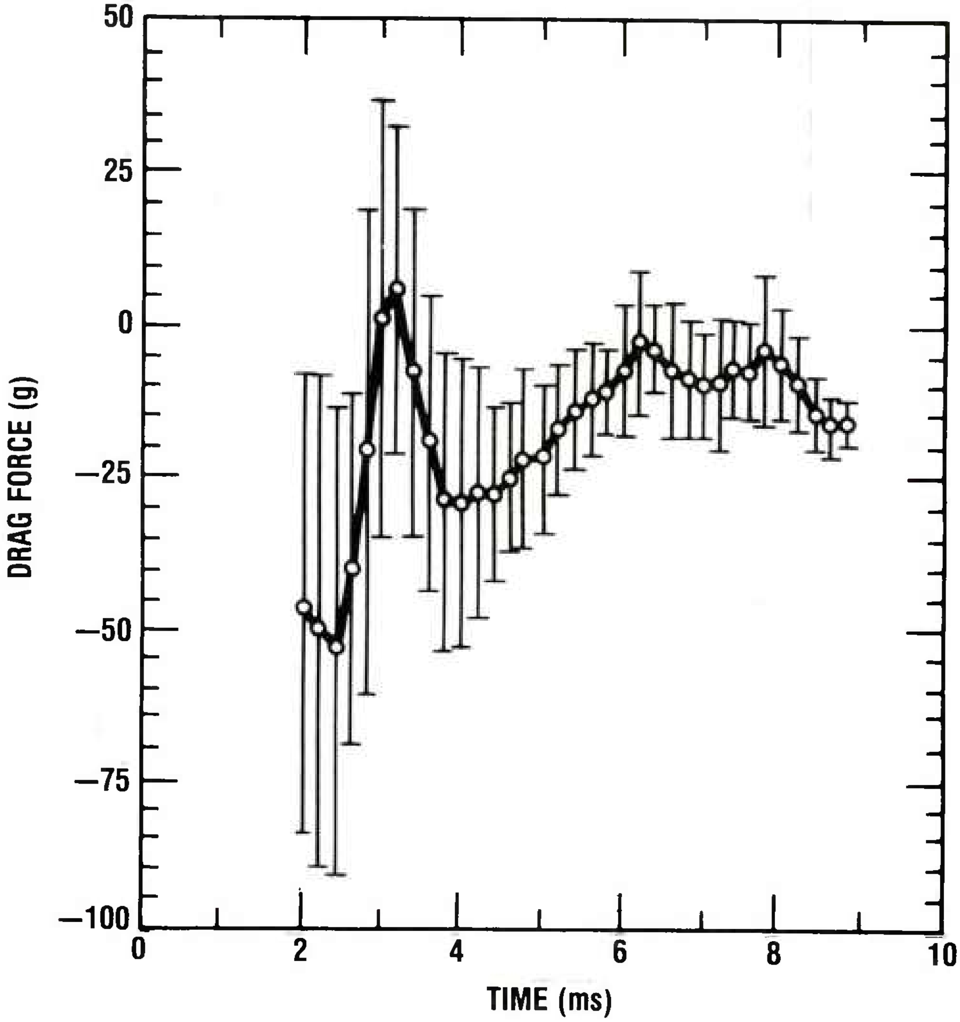


Figure 16. Drag simulation ($8 \times 10^3$-g setback level).

*5.3.2.4 $16.0 \times 10^3$-g Setback Tests*

The drag phase of the test discussed in section 5.3.1.3 and appendix D continues to indicate well-defined and repeatable production of drag force. The 10 tests analyzed here indicate an average drag force, settling down to about −40 g by end of record (8.0 ms). This trend is shown in figure 17. As in the previous section, the standard deviation here shows a continual improvement with time, and by 7.6 ms the average value of drag force is −41.9 ± 5.4 g. Thus, one can say with 95-percent confidence that at the 7.6-ms time mark 90 percent of all similar tests will produce drag forces between −26.6 and −57.2 g. Again, at the 95-percent confidence level, 87.5 percent of all tests will produce drag forces of at least −30.6 g. Assuming the trend indicated by the graph continues, drag forces of this character will probably exist beyond 8 ms.

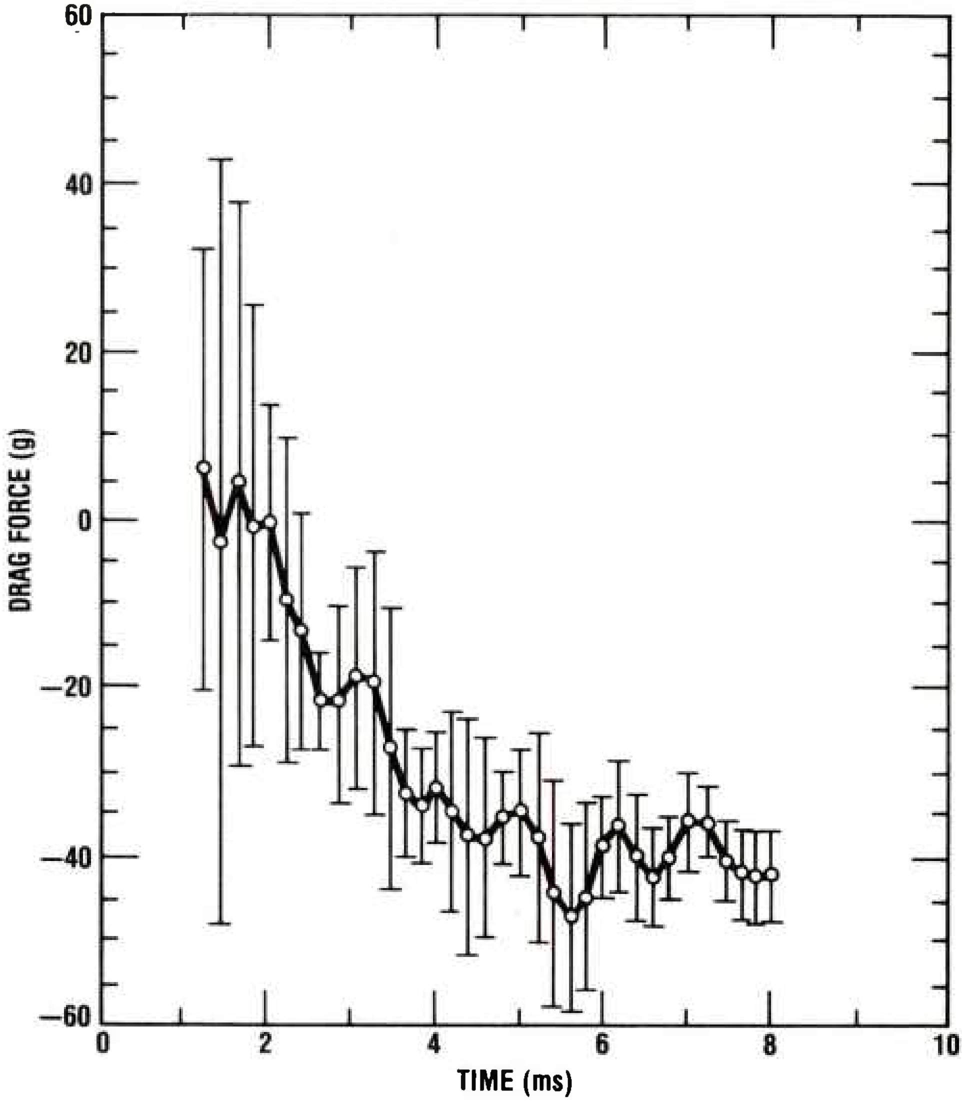


Figure 17. Drag simulation (16 × $10^3$-g setback level).

## 6. CONCLUSIONS

The validity of the setback and drag simulation techniques has been demonstrated. Within the tolerances outlined above in sections 5.3.1 and 5.3.2, tests are clearly repeatable. The adjustable range of setback forces from 4,000 to 16,000 g and drag forces from 0 to −30 g has been achieved. Low values of drag (say, in the vicinity of −5 g) seem less repeatable than the higher values. Values of the setback force and drag force obtained in a single test can be determined only from a streak camera photograph of the event. Results of many tests indicate that drag forces are generated with a reliability such as already discussed.

## 7. RECOMMENDED IMPLEMENTATION

The intended procedures related to XM754 Viper fuze testing, Reference M15-28735A (especially paragraphs 3.2.1.2 and 4.3.2.2), should be implemented.

## APPENDIX A.—DETERMINATION OF PROJECTILE IMPACT VELOCITY

The passage of the projectile by the optical pickup near the muzzle of the air gun generates an electrical pulse whose width is proportional to the length of the projectile and the projectile's speed. In general, the time (t) which the test projectile, of length d, takes to pass the optical pickup determines the impact velocity (u):

$$u = d/t.$$

The design of the projectile may cause an improper time to be generated. Protrusions such as screw heads on the rear of the projectile may cause an increase in the time of passage if they are in line with the optical pickup. Undercutting the central portion of the projectile to reduce weight may cause the indicated time of passage to be much shorter than the correct value. Some consideration of the location and operation of the optical pickup should be given during the design of a test projectile.

The alignment procedure insures that the inner bores of the air gun and drag tube are coincident—a necessary condition for a smooth transition of the projectile from the air gun to the drag tube.

A special alignment gauge is used to determine the amount and direction of the displacement of the drag tube axis relative to the gun tube axis. The gauge consists of an aluminum cylinder 2.992 in. (7.600 cm) in diameter and 15.3 in. (38.8 cm) long. A 1.25-in. (3.17-cm) diameter steel rod projects out about 6 in. (15.24 cm) from one end of the aluminum piece. See figure 10, body of report. The gauge is inserted into the muzzle end of the gun tube with the steel rod spanning the gap between the gun and the drag tube. On the end of the rod is a small post which carries a hinged metal finger. When the finger is made to touch the inner wall of the drag tube, the relative displacement of the rear end of the finger from the post is measured with a micrometer (see fig. B-1). Four such measurements made around the inner circumference of the drag tube will permit the vertical and horizontal displacement of the drag tube axis to be calculated. Shims are used to compensate for the vertical displacement, and a lateral positioning of the support brackets will align the drag tube horizontally. (Lateral movement is facilitated by a micrometer head which can be mounted to bear against the support bracket and permit minute adjustments.)

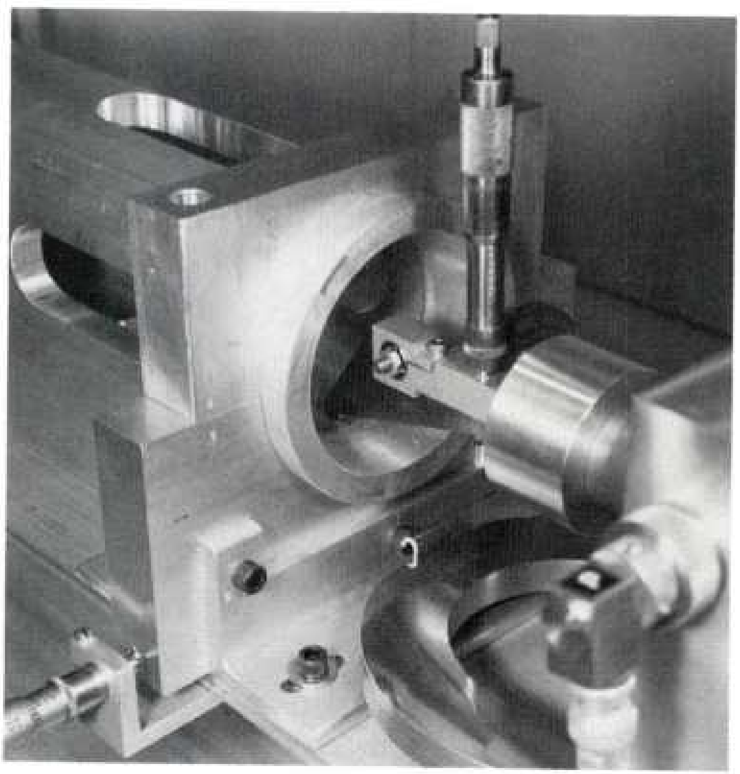

Figure B-1. Using the alignment gauge.

APPENDIX C.—EXAMPLES OF PROJECTILES, MITIGATORS, AND MEMs FOR DIFFERENT SET-BACK FORCES

Different setback forces are obtained by changing the weights of the projectile and the momentum exchange mass (MEM) and by changing the shape of the mitigator and the material from which it is made. Some examples of these variations are given below.

(a) $4.0 \times 10^3$-g level
*Projectile*: (As described in sect. 3.6 body of report.)

Material—Bakelite
Diameter—2.992 in. (7.599 cm)
Length—3.812 in. (9.682 cm)
Accommodates three Viper fuzes
Total weight—1.58 lb (718 grams)

*Mitigator*: (As described in section 3.7, body of report.)

Material—7-ply marine plywood 0.75 in. thick (1.91 cm)
Dimensions—2.0- × 2.0-in. blocks (5.0 × 5.0 cm)
Quantity—Seven blocks taped together per mitigator
Overall size—2 × 2 × 5.25 in. ( 5 × 5 × 13.3 cm)
Weight—7.2 oz (200 grams), approx.

*MEM*: (As described in section 3.7, body of report.)

Material—Brass, with four Bakelite runners
Diameter (of brass piece)—2.7 in. (6.85 cm)
Diameter overall—2.990 in. (7.594 cm)
Length—4.06 in. (10.31 cm)
Total weight (including drag washer)—7.03 lb (3.19 kg)

These three components are shown in figure C-1.

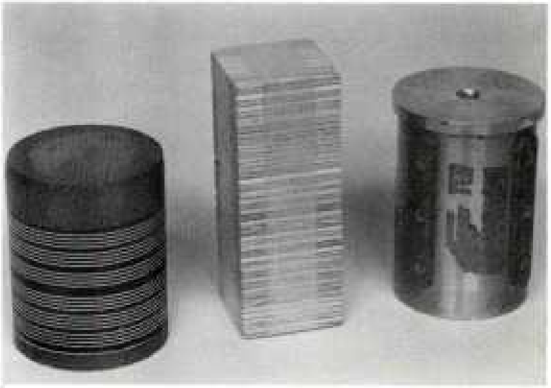

Figure C-1. Components for $4 \times 10^3$-g setback.

(b) $8.0 \times 10^3$-g level

*Projectile*:

Material—Bakelite
Diameter—2.992 in. (7.599 cm)
Length—3.24 in. (8.23 cm)
Accommodates one Viper fuze
Total weight—0.937 lb (425 grams)

*Mitigator*:

Same as described in part (a), above.

*MEM*:

Material—Brass, with four Bakelite runners
Diameter (of brass piece)—2.7 in. (6.85 cm)
Diameter, overall—2.990 in. (7.594 cm)
Length—2.82 in. (7.16 cm)
Weight (including drag washer)—4.72 lb (2.14 kg)
(Requires holes drilled into brass to attain the proper weight.)

These three components are shown in figure C-2.

Figure C-2. Components for 8 × $10^3$-g setback.

(c) 16.0 × $10^3$-g level

*Projectile*:

Material—Bakelite
Diameter—2.992 in. (7.599 cm)
Length—2.97 in. (7.56 cm)
Accommodates one Viper fuze
Weight—0.952 lb (0.432 kg)
(Length of projectile may have to be adjusted for this weight when carrying Viper fuze. Above dimensions are for other types of payload.)

*Mitigator*: Refer to figure C-3.

Material—Aluminum tubecore
Crush strength—3.3 k-psi (0.23 k-bar)
Diameter—2.37 in. (6.02 cm)
Length—1.03 in. (2.62 cm)
Weight—0.953 oz (27.0 grams)

*MEM*:

Material—Brass, with four Bakelite runners
Diameter (of brass piece)—2.87 in. (7.29 cm)
Diameter, overall—2.990 in. (7.594 cm)
Length—5.50 in. (1.97 cm)
Weight (including drag washer)—10.69 lb (4.85 kg)

These three components are shown in figure C-4.

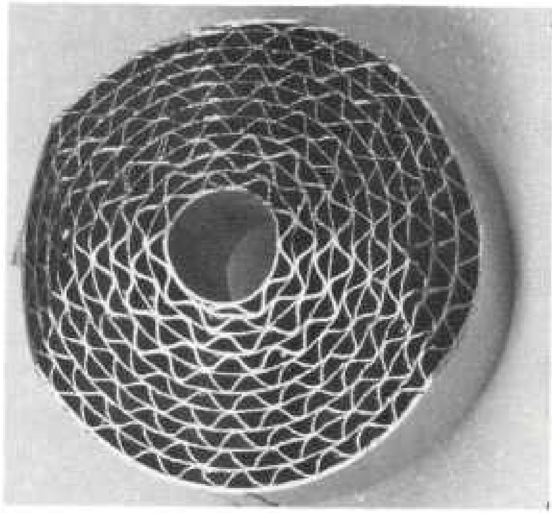

Figure C-3. Aluminum tubecore mitigator.

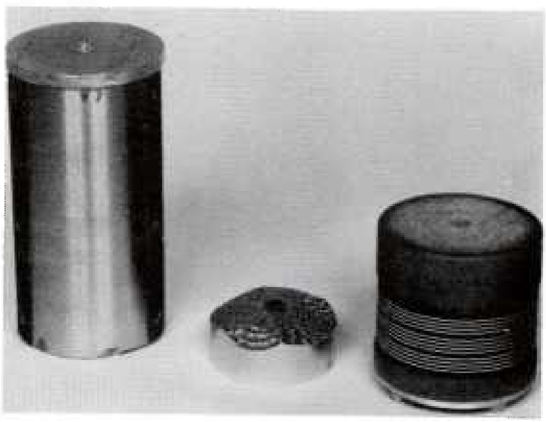

Figure C-4. Components for 16 × $10^6$-g setback.

## APPENDIX D.—TEST PARAMETERS

Three series of tests were analyzed in section 5.3 (body of report). Each series required different test parameters to achieve the setback and drag forces indicated. The particular parameters of interest are contained in the test report of a representative test in each series. Copies of such are presented as follows.

(a) $4.0 \times 10^3$-g level (See sect 5.3.1.1, body of report.):
figure D-1, test 52, 9 October 1979.

(b) $8.0 \times 10^3$-g level (See sect. 5.3.1.2, body of report.):
figure D-2, test 24, 12 September 1980.

(c) $16.0 \times 10^3$-g level (See sect. 5.3.1.3, body of report.):
figure D-3, test 181, 14 August 1980.

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              S E T B A C K - D R A G   T E S T E R   R E P O R T
SHOT NUMBER 52                        TIME 1440 HOURS                      9-OCT-79
TEST DATA                          PROJECT -- 898CH7
                                 REQUESTOR -- MR. MICOM
                                 COMPONENT -- VIPER
                            UNIT NUMBER(S) -- 16,17,18
                               TEMPERATURE -- 70 F, 21 C
PROJECTILE #1 (FLAT NOSE)
                            WEIGHT     1.58   POUNDS              0.718 KILOGRAMS
                            LENGTH     3.80   INCHES              9.65  CM.
GUN  (EVACUATED BARREL)
                   INSIDE DIAMETER     3.00   INCHES              7.61  CM.
                    OVERALL LENGTH    11.83   FEET                3.61  METERS
                  FIRING PRESSURE     14.7    PSIA                1.00  ATMOSPHERES (ABS)
                    PHOTOCELL TIME  1724.     MICROSECONDS
          NON-DIMENSIONAL LENGTH     0.0226
                       PERFORMANCE    83.4    %
MITIGATOR (MOUNTED ON MEM)
     2X2 INCH PLYWOOD SQUARE
                            WEIGHT     7.34   OZ                208.    GRAMS
                    INITIAL LENGTH     5.23   INCHES             13.28  CM
                    CRUSHED LENGTH     4.40   INCHES             11.18  CM
MOMENTUM EXCHANGE MASS (MEM)
     WEIGHT (WITH MITIGATOR)           7.03   LB                  3.19  KILOGRAMS
DRAG TUBE
              MEM WASHER DIAMETER      2.850  INCHES              7.24  CM
     INITIAL MITIGATOR DEPTH           5.00   INCHES             12.70  CM
              FINAL BIRD POSITION     28.8    INCHES             73.2   CM
RESULTS
   MAX. LAUNCH ACCELERATION           65.4    g
                  IMPACT VELOCITY    184.     FT/SEC             56.0   METERS/SEC
      BASED ON CONSTANT DECELERATION CALCULATIONS:
                STOPPING DISTANCE      1.6    INCHES              4.0   CM
            AVERAGE ACCELERATION       4.0    KILO g
                      IMPACT TIME      1.43   MILLISECONDS
  BASED ON PREVIOUS TESTS USING THIS TYPE OF MITIGATOR, THE
           PEAK ACCELERATION IS        4.1    KILO g
COMMENTS:
CAMERA OPERATOR, MR MARY.      (SPEED 56.2 RPS)
TEST PERFORMED BY MR. MARY, BRANCH 48500, EXT 42804.
                                                 DENSITY OF STRIPES  169
                                         DENSITY BETWEEN STRIPES  55
                                                                SUM  224
                                                   SUM DIVIDED BY 2  112
                                                          SUBTRACT  2 0
                                                 T H R E S H O L D  92
X STEP = 2800 (REPRESENTS 50 MICROSECOND TIME INTERVALS)
NUMBER OF SCANS = 391 (70 MM FILM)    10 SCANS PER INCH

TAN < = .889951                TRAVEL PER INTVL = 2.49186 MM
ON DRAG PORTION - X STEP = 11200 (REPRESENTS 200 MICROSECOND TIME INTERVALS)
NUMBER OF SCANS = 118 (70 MM FILM)    3 SCANS PER INCH

TAN < = .889951                TRAVEL PER INTVL = 9.96745 MM

IDENT....0052 SAD XXXX (THRESHOLD)
```

Figure D-1. Parameters for 4 × $10^3$-g level test.

```
        S E T B A C K - D R A G   T E S T E R  #2 R E P O R T
Shot Number 24              Time 1301 Hours                12-SEP-80
                        Project -- 816089
                      Requestor -- Mr. STARBUCK
                      Component -- VIPER
                 Unit Number(s) -- Q-6
                    Temperature -- 140 F, 60 C
PROJECTILE #6 (FLAT Nose)
                         Weight    0.937 lb            0.425 kgm
                         Length    3.24  in.           8.23  cm
GUN  (Evacuated Barrel)
                Inside Diameter    2.99  in.           7.61  cm
                 Overall Length   11.83  ft            3.61  m
                Firing Pressure   14.70  psia          1.00  atm abs
                 Photocell Time 1073.0   microsec
        Non-Dimensional Length    0.0381
                    Performance   88.6   %
MITIGATOR (Mounted on Bird)
  2X2 in. PLYWOOD SEVEN PLY
                         Weight    7.02  oz          199.    gm
                 Initial Length    5.27  in.          13.39  cm
                 Crushed Length    4.35  in.          11.05  cm
MOMENTUM EXCHANGE MASS (MEM)
                         Weight    4.72  lb            2.14  kgm
DRAG TUBE
            MEM Washer Diameter    2.850 in.           7.24  cm
 Mitigator Position in Slot        0.750 in.           1.91  cm
  Bird traversed drag tube into catcher.
RESULTS
    Max Launch Acceleration   110.5    g
            Impact Velocity   252.     ft/s           76.7    m/s
    A Constant Setback Assumption Yields:
           Stopping Distance    1.7    in.            4.3    cm
        Average Acceleration    7.0    kilo-g
                 Impact Time    1.12   ms
    Previous tests using this type of mitigator imply:
           Peak Acceleration    7.6    kilo-g
COMMENTS:
Camera Operator, Mr. NELSON.     (Speed 58.4 rps. # 3)
PHOTO TIME ADJUSTED FOR LAND-LENGTH:TOTAL-LENGTH RATIO.
Test Performed by Mr. NELSON, Branch 48500, ext 42804.
                              DENSITY OF STRIPES ____________

                         DENSITY BETWEEN STRIPES ____________

                                             SUM ____________

                                SUM DIVIDED BY 2 ____________

                                     SUBTRACT      2 0

                               T H R E S H O L D ____________
X STEP = 1500 (REPRESENTS 25 MICROSECOND TIME INTERVALS)
NUMBER OF SCANS = 664 (70 MM FILM)    17 SCANS PER INCH

TAN < = 1.17325             TRAVEL PER INTVL = 1.75987 MM
ON DRAG PORTION - X STEP = 11700 (REPRESENTS 200 MICROSECOND TIME INTERVALS)
NUMBER OF SCANS = 118 (70 MM FILM)    3 SCANS PER INCH

TAN < = 1.17325             TRAVEL PER INTVL = 13.727 MM
C A U T I O N: CONSIDER CUTTING X STEP IN HALF!
```

Figure D-2. Parameters for 8 × $10^3$-g level test.

```
          S E T B A C K - D R A G   T E S T E R   R E P O R T
Shot Number 181               Time 1055 Hours                  14-AUG-80
                    Project -- 836085
                  Requestor -- Mr. NORDEEN
                  Component -- 120MM
             Unit Number(s) -- 113
                Temperature -- 70 F, 21 C
PROJECTILE #H-7 (FLAT Nose)
                     Weight     1.190 lb              0.540 kgm
                     Length     3.16  in.             8.03  cm
GUN  (Evacuated Barrel)
            Inside Diameter     2.99  in.             7.61  cm
             Overall Length    11.83  ft              3.61  m
            Firing Pressure    14.70  psia            1.00  atm abs
             Photocell Time  1221.0   microsec
     Non-Dimensional Length     0.0300
                Performance    85.2   %
MITIGATOR (Mounted on MEM)
     2X2 in. TUBECORE ROUND
             Crush Strength     5.0   kilo-psi        0.34  kilo-bar
                     Weight     0.882 oz             25.0   gm
             Initial Length     1.027 in.             2.61  cm
               Single WEDGE     0.500 in.             1.270 cm
             Crushed Length     0.385 in.             0.978 cm
MOMENTUM EXCHANGE MASS (MEM)
Weight (exluding Mitigator)    10.69  lb              4.85  kgm
DRAG TUBE
          MEM Washer Diameter   2.985 in.             7.58  cm
    Initial Mitigator Depth     4.40  in.            11.18  cm
  Bird traversed drag tube into catcher.
RESULTS
    Max Launch Acceleration    87.0   g
            Impact Velocity   216.    ft/s           65.7   m/s
    A Constant Setback Assumption Yields:
           Stopping Distance    0.71  in.             1.8   cm
        Average Acceleration   12.1   kilo-g
                Impact Time     0.55  ms
COMMENTS:
Camera Operator, Mr. NELSON.     (Speed 54.7 rps)
Test Performed by Mr. NELSON, Branch 48500, ext 42804.
                                        DENSITY OF STRIPES ____185____

                                   DENSITY BETWEEN STRIPES ____53____

                                                       SUM ____238____

                                        SUM DIVIDED BY 2 ____119____

                                              SUBTRACT       2 0

                                        T H R E S H O L D ____99____
X STEP = 1400 (REPRESENTS 25 MICROSECOND TIME INTERVALS)
NUMBER OF SCANS = 742 (70 MM FILM)   19 SCANS PER INCH

TAN < = 1.0736              TRAVEL PER INTVL = 1.50303 IN
ON DRAG PORTION - X STEP = 10900 (REPRESENTS 200 MICROSECOND TIME INTERVALS)
NUMBER OF SCANS = 118 (70 MM FILM)   3 SCANS PER INCH

TAN < = 1.0736              TRAVEL PER INTVL = 11.7022 MM

IDENT....0181 SAD XXXX (THRESHOLD)
Camera Number 3
```

Figure D-3. Parameters for 16 × $10^3$-g level test.

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